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FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT
CD NO.

COUNTRY USSR

DATE OF INFORMATION 1948

SUBJECT Automotive Industry - machining of gears

HOW PUBLISHED Monthly periodical

DATE DIST 16 December 1948

WHERE PUBLISHED Moscow

11999

NO. OF PAGES 6

DATE PUBLISHED February 1948

SUPPLEMENT TO 00-W-938

LANGUAGE Russian

THIS IS UNEVALUATED INFORMATION FOR THE RESEARCH USE OF TRAINED INTELLIGENCE ANALYSTS

SOURCE IDENTIFICATION Avtomobil'naya Promyshlennost', No 2, 1948. (Translation specifically requested.)

LABOR-SAVING METHODS IN MACHINING CYLINDRICAL GEARS FOR AUTOMOBILES

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Profile Shaping

In 1945 the "Komsomolets" Plant put out a gear-shaping machine for the semi-finished cutting of cylindrical gears with external meshing and spur or oblique teeth. It could also be used for clutch teeth machined by the profile-shaping method.

The tool consists of a set of profile cutters, shaped like the recess of the tooth, which machine each recess on the wheel. The cutters are inserted in slots in the big enclosing cutter head. The wheel is cut by reciprocal motion of the spindle, to which the blank being machined is securely fastened.

Before the beginning of each upward working stroke of the blank, the cutters are brought closer to the center by action of a conical arrangement on the external ring which converges the teeth in proportion to the feed.

The cutter head can be used only for gears of a particular diameter and number of teeth. The first model of the machine made by the "Komsomolets" Plant can be used for gears up to a diameter of 100 millimeters and module of 5.

According to published data, a machine of this type assures an output of 60 to 100 gears per hour, and is between 5 and 20 percent faster than any other method.

Experimentation with gears of module 2.5 or higher has shown that while profile shaping secures an increased output, its precision lags considerably behind that achieved by the process of generating. The manufacture and precision grinding of the tool assembly is extremely complex and the life of the tool is short. The method of profile shaping should be further developed, however, and its use in rough operations expanded.

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Semifinished Gear Hobbing

Due to its great productive capacity, hobbing is becoming one of the most extensively used methods, even for semifinished gear cutting.

To make the hobbing process more effective, more rigid machines, similar to those for rough gear cutting, must be employed, and supplementary devices used for increasing their accuracy (ground transmission gearing, compensating mechanisms for the play in the worm, etc.). Operating conditions for a hobbing cutter: v equals 30 to 40 meters per minute, s equals 1.5 to 3 millimeters per revolution.

Semifinished gear hobbing is used in the shortened [when teeth have been cast on the blank] as well as in the full process [when gear is made entirely by machining].

Under conditions of mass production in the full process, particularly for gears with oblique teeth, a device should be worked out guaranteeing the accurate alignment of the hobbing cutter with the thread for the uniform distribution of tolerance. The Type 534 machine of the "Komsomolets" Plant, equipped with such a device, is shown (photograph available in CIA as Photo Accession No 3001).

The necessary precision of the blanks under shaving is assured by the precision of the hobbing machine, hobbing cutters, and the holders for the blanks. To increase the life of the shaver, the shaving allowance at the tooth crest of gears with 15 teeth or more should be gradually reduced to zero, while some undercutting of the profile should be done at the root. The profile of hobbing cutters should be triangular.

If these specifications were adhered to, the precision of gears milled on gear-hobbing machines would be considerably higher than that of gears with broached teeth or those machined by profile gear shaping.

Further increase in the productivity of semifinished gear hobbing depends on the same improvements necessary for rough hobbing. Here it is necessary to overcome some difficulties with respect to profile grinding of cutters, equipping with hard alloys, the selection of hard alloys, etc.

Semifinished Gear Shaping

Semifinished shaping is less productive than other methods and is used only when the full machining process is being carried out.

This operation, like gear hobbing, requires proper precision of machines, shapers, and block supports. The shapers should have special profiles which assure their ability to work within the shaving and shearing allowance of the tooth's crown.

Shaving

Shaving, which accomplishes a significant saving of labor in the manufacture of gears, has almost universally replaced gear shaping and gear hobbing in finished operations in the automobile industry. Highly productive and inexpensive, this operation secures high precision in the making of gears. The method permits modification of the profile, compensation for distortion in heat-treatment, and prevention of the so-called shredding (kromchatyy) contact between the teeth (by means of shearing teeth at profile height, by use of barrel-shaped forms, etc.). This permits decreasing the allowance for subsequent lapping operations and at the same time speeds up the output and cuts down the cost of manufacture remarkably.

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Until recently, shaving wa CONFIDENTIAL gears of module 2 to 4.5, with a diameter of initial periphery of 50 to 250 millimeters. During the war, the shaving of both small module gears (module 0.5. with diameters from 10 millimeters) and gears of module 4.5 to 7 with diameter up to 450 millimeters was adopted. A specially designed machine was used.

Figure 11 (Photo Accession No 3002) shows a machine for shaving gears of small module while Figure 12 (Photo Accession No 3003) shows a machine for shaving gears up to module 6 and initial periphery diameter up to 450 millimeters. The article is placed in a high-speed clamping device on the rotating table having heavy-duty drive. The machine is equipped for machining heavy blanks and has a special loading crane for this purpose.

Profile shavers, as a rule, do not do evolute shapes cleanly. They are adjusted for compensation of the stable deformations received in heat treatment and the deformations imparted in the shaving process.

The precision of shaving depends almost entirely on the precision of the blank. When shaving, only rectification of the gear's profile, not cutting of new surface, takes place. The possibilities of rectifying the various elements of the meshing vary. To rectify flaws of spacing, or dispersion of declination, is more difficult than to eliminate beats and local flaws in profile.

The allowance for shaving is set at a minimum because repeated passes of the blank under the shaver leads to cold-hardening of the machined surface, lowered possibility of rectification, deformation in subsequent heat treatment, and damage to the shaver. The allowance under shaving on two sides of a tooth should be equal to about 0.8 of the sum of the flaws in the meshing elements, reckoned at the line of meshing. The allowance will vary with the height of the tooth.

The worst problem, which up until now has been practically unsolved, is the durability of the shaver. The advertising data put out by American firms on the life of shavers up to 25,000 gears are confirmed by neither American nor Soviet experience.

Actually, shaver life on a medium module, medium carbon steel gear is rarely as much as 6,000-8,000 gears.

The variation in acoustic qualities and the profile contact of the shaved gears, as well as the machined surface, must be considered criteria of gear-shaver wear when pairs of first-class precision gears are being tested on calibration instruments (not more than 0.8 microns).

For criteria of bluntness in second-class precision gears it is necessary to take the deterioration of the rectification, i.e., the change in properties indicated when verifying on an apparatus with metal-to-metal contact.

Visible wear of the shaver usually does not come out in the profile, while for first-class gears, deterioration is not even visible in the geometric symmetry. The following table shows the mean statistical data for the life of shavers for gears of second pitch dimensions, worked out in conformity with established criteria for dulling (in number of parts shaved):

Class	Carbon Steel	Alloyed Steel	Cast Iron
First	2,000	1,000	500
Second	3,000	1,500	600

With the aim of increasing the durability of shavers and the consequent profitability of shaving, the following is recommended:

Shavers should be made with 125-, not 50-millimeter apertures in the form of a shaver ring. At the time of forging the shaver ring should be well rolled without increasing the heat; this increases the durability of the shaver by 20 or 25 percent. The life of shavers with detachable teeth of the Gorkiy Automobile Plant type, or shavers having built-up blades is also above the usual.

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To prevent the shaver from chipping at the moment of reversal of stroke, it is necessary to use a pawl with a gradual feed. In addition to rational distribution of shaving allowance along the height of the gear, another factor in the life of a shaver is the uniform distribution of load of shaving along the whole length of the shaver tooth. This is accomplished by the so-called diagonal shaving method. A new machine with an auxiliary drive across the shaver at an angle to its axis has recently been produced (photograph available in CIA as Photo Accession No 3004). According to published data this method increases the life of the shaver and raises the productivity of the process by means of a planing action on the shoulder of the shaver, which also improves the precision of the tooth alignment.

The quality and purity of cutting fluids also play an important role in increasing shaver life.

The life of shavers shown in the above table could be doubled with the adoption of strict allowance maintenance, high-alloy fast-cutting steels for shavers, and the use of fine-grain steel (McQuaid rating 4 to 6) for gears.

Gear-Lapping Operations

Gears acquire stable and unstable deformations in heat treatment. The influence of the first, as the name indicates, must be compensated by profile correction of the gear.

The unstable deformations of gears in the process of heat treatment can be counteracted by: (1) using steels not giving a noticeable volume of modification under heat (Type SAE 4640, etc.) and fine-grain steel (McQuaid 4 to 6) with variants of carbon up to 0.05 percent; (2) establishing special control over uniformity of microstructure; (3) using special methods of heat treatment (low-temperature treatment, etc.); (4) high-frequency tempering of gears according to contour; and (5) by making more precise experimental batches for each new series of gears from the metal of one melt.

Unstable deformations after heat treatment are eliminated by lapping and working-in gears. But if the above-enumerated measures are adopted, the unstable deformation will be reduced to the minimum, and the lapping and working-in operations can be concentrated on improving the quality of the surface.

The widespread notion that lapping and working-in are not effective and are damaging to the geometrical parameter has caused misuse of these operations.

In the automobile industry lapping of gears is done on the "Komsomolets" Plant Model 573 lapper (photograph available in CIA as Photo Accession No 3005) with a dual-purpose cast iron lap: drag (uni-profilic lapping) and thrust (bi-profilic lapping). The work regimen with the machines should be so arranged that there is a constant maximum slip speed on a lap of specific stress for all heights of profile.

Working-in a pair of precision gears requires the use of axial and radial movement in addition to rotary movement. Working-in does not improve the precision of gears with respect to geometrical form, but can cut down the noise of a pair as much as 10 decibels and make them less susceptible to assembly errors in the crankcase.

The effectiveness of lapping operations can be improved by using better chemical abrasives, stabilizing flywheels, and more rigid machines. Experiments should be conducted on internal-tooth lappers (photograph available in CIA as Photo Accession No 3006).

Milling or Machining Gears on Slotting Machines?

Comparison of semifinished gear milling and gear shaping permits us to make the following deductions:

At present the productivity of the two are about equal, although the introduction

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of sectional hobbing cutters, hard alloys, rigid machines, and tangential feed makes the milling of gears prospectively twice as productive as gear shaping.

Sectional hobbing cutters and tangential feed results in a 25 to 30 percent reduction of tool outlay.

Hobbing cutters with triangular profiles are much simpler to manufacture than gear-shaper cutters of the same profile for gears with oblique teeth.

Tooth-surface quality achieved when slotting gears with uni-passage pawls and medium feed is about the same as that achieved in milling (1 to 1.25 microns), but to correct flaws by shaving is simpler after milling than after slotting.

Gear-slotting machines are more sensitive to loss of precision than gear-milling machines and need more frequent checking and stoppage for repairs.

For all situations where the job permits milling, this process must be preferred to slotting both in semifinished and rough operations.

However, for rough operations on gears of both second and third pitch dimensions, slotting could, with further improvement, become profitable in the full technological process.

Complete or Shortened Process?

One must not confuse the choice of milling or slotting with operation by the full (including rough cutting) or shortened (uni-passage) cycle of machining gears.

The lack of an adjusting device assuring accurate alignment with the thread in two-way milling often dictates the selection of the shortened process. Machine-tool manufacturers and automobile plants should modernize gear-cutting machines to use two-way milling.

From the point of view of economy the short process is entirely suitable for first-pitch gears, but entirely improper for gears of the third-pitch dimensions. The shortened process is more economical than the full on second-pitch gears, but its effectiveness in this case has not been fully demonstrated.

According to published data, the full process used on 28-tooth gears of module 6 is 25 percent more productive than the shortened process. The number of machines required was almost halved and expenditure of tools substantially lowered.

According to data of the Automobile Plant imeni Stalin, the machine time for rough milling and semifinished milling is 9.8 minutes, and the unit time on 44-tooth 3.75 module gears machined by the full process, 14.8 minutes. The shortened process machine time is 8 minutes and the unit time 10 minutes.

The outlay for tools in the full and shortened cycles for gears of second-pitch dimensions is about the same. The cost of equipment and other overhead in the case of the shortened process is sharply reduced. For gears of the first-pitch dimensions the gain in productivity is 100 percent, while the cost for equipment and tools is less than half.

The expediency of using the short cycle in automobile plants is clear. But success depends on the maintenance of rigid tolerances in the manufacture of hobbing cutters, preventative inspection and repair, and repair of hobber dividing heads on gear-milling machines.

As previously mentioned, semifinished milling has little influence on the precision of a gear if the machine is in good order, but sharply cuts down the precision

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if the machine has backlash in it. Therefore, it is recommended that in the near future the full technological process be adopted for (1) gears of 18 teeth or less, of first-class precision and second-pitch dimensions and (2) for gears of third-pitch dimensions. The shortened cycle is recommended for (1) gears of first-pitch dimensions and (2) gears of second-class precision and second-pitch dimensions.

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